CONDITIONS UNDERLYING THE INFECTION OF WOUNDS.

By WILLIAM H. WELCH, M.D.

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CONDITIONS UNDERLYING THE INFECTION OF WOUNDS:

INCLUDING A DISCUSSION OF DISINFECTION WITH REFERENCE TO TREATMENT OF WOUNDS, OF THE RELATION OF BACTERIA TO SUPPURATION, OF THE RESISTANCE OF TISSUES TO THE MULTIPLICATION OF BACTERIA, AND OF THE EFFECTS OF ANTISEPTIC AGENTS ON WOUNDS.

BY WILLIAM H. WELCH, M.D.,

Professor of Pathology, Johns Hopkins University.

THAT the presence of certain kinds of bacteria is an essential condition of wound infection is a fact so well established, and so generally recognized, that no discussion as to this point is likely to arise in this assembly. The practical results of the application of this doctrine to the management of wounds are the most eloquent testimony to its life-saving truth. The recognition of this truth, even before its complete demonstration, and the introduction of methods of wound treatment based upon it, will remain the immortal merit of Lister, even although every detail of his treatment be replaced by measures found by riper experience to be better suited to the purpose.

The simple conception which was the basis of early antiseptic procedures in surgery—that a wound to which bacteria gain access becomes infected in the same way as a sterilized infusion of meat undergoes putrefaction when a single suitable germ enters—has been greatly modified. Furthermore, it is found that the traumatic infections present their own peculiar problems, which must be studied by themselves, and cannot be solved by analogies drawn from observations of other specific infections, such as anthrax and the septicæmias of the lower animals. The study of wound infections involves the consideration of many varying and often complicated factors, relating both to the agents of infection and to the individual exposed to infection.

Without consuming time with any historical review, I shall proceed at once to indicate some of the questions which are of especial importance, and which may be profitably considered in this discussion.

What are the microörganisms concerned in the infection of wounds, and how do they act?

How are we to explain the great differences in the effects produced by the pyogenic bacteria, their apparent harmlessness under some conditions, their fatal virulence in others?

What are the ways by which bacteria gain access to a wound?

How often are bacteria to be found in wounds treated antiseptically or aseptically? What are the characters of these bacteria and whence do they come?

What are the best means of surgical disinfection?

No attempt can be made on this occasion to treat exhaustively a single one of these questions. My aim will be to present a brief survey of our knowledge, as well as of the defects in our knowledge, concerning some of the more important questions; to offer some results of personal observation and experiment, and to indicate in conjunction with the co-referee the lines which this discussion may follow. It does not seem necessary, indeed it would be presumptuous before this audience, to dwell in detail upon established facts which are the common property of all who are interested in the subject.

So far as personal observations and experiments are concerned, I may say that these have been made in the Johns Hopkins Hospital and Pathological Laboratory, and that I am indebted to several of my colleagues and co-workers there for work which they have done either independently or under my supervision. I take this opportunity of acknowledging especially the assistance of Drs. Halsted, Abbott, Ghriskey, Robb, and Howard.

This paper will relate only to the ordinary inflammatory and suppurative traumatic affections, and not to specific wound infections, like tetanus, diphtheria, and hospital gangrene.

It would be wearisome on this occasion to consider or even enumerate all the bacteria which have been found in suppurative and other traumatic inflammatory processes, so that in this connection I shall touch only upon a few points drawn chiefly from our own experience.

We have found the staphylococcus pyogenes aureus far more frequently than any other species of bacteria in furuncles, abscesses, osteomyelitis, and other forms of suppuration. The prevalence in Strassburg, according to Levy, of the staphylococcus pyogenes albus in all kinds of suppurative inflammation (excepting furuncles), raises the question whether there may not be differences in different regions as regards the relative frequency of the various kinds of pyogenic cocci.

We have, however, met a white staphylococcus in a certain class of cases with great frequency, viz., in small stitch abscesses, and in the slighter grades of inflammatory disturbance of wounds treated antiseptically or aseptically. This coccus has been often seen by Bossowski and others in the same class of wounds, and has been hitherto identified with the staphylococcus pyogenes albus of Rosenbach, but

we have some hesitation in so regarding the micrococcus which we have found in the cases mentioned. The staphylococcus pyogenes albus is generally described as not differing essentially from the aureus, except by the absence of the yellow color in the cultures. This coccus, however, differs from the staphylococcus pyogenes aureus in much greater slowness of liquefaction of gelatin and of coagulation of milk, and in far less virulence when inoculated into the circulation of rabbits. It may be an attenuated form of the staphylococcus pyogenes albus. Until this is settled I propose to call it the staphylococcus epidermidis albus, as it is an almost constant inhabitant of the epidermis, as will be apparent when I come to speak of the bacteria in aseptic wounds. I shall only add here that this coccus may be present in graver suppurative inflammations, but then it has been nearly always associated with some other pyogenic organism, or has assumed the form of the typical staphylococcus pyogenes albus.

It is, perhaps, not out of place to remark that the diagnosis of the staphylococcus pyogenes albus in cultures from abscesses and other suppurations should not be made too hastily. It may require several days before colonies of the aureus assume a distinct yellow color. Cultures upon potatoes are particularly favorable for the speedy development of this color. There may be marked differences in the rapidity with which different colonies of the aureus from the same source and in the same plate or roll cultures turn yellow.

The efforts to differentiate into distinct species the pathogenic streptococci have thus far met with little success, so that the weight of opinion favors the view that the streptococci of erysipelas, of phlegmonous inflammations, of septicæmia, of puerperal fever, and of various forms of angina, belong to one and the same species. In conformity with the results of most investigators I have been unable to determine any decisive differences between the streptococcus erysipelatos and the streptococcus pyogenes. Von Lingelsheim has recently divided the streptococci into two groups : one non-pathogenic, called the streptococcus brevis, and the other pathogenic, the streptococcus longus. Among the points of distinction which he gives there is one which I have not found constant, viz., the invisible growth of all pathogenic streptococci upon potato. The behavior is usually as stated by Von Lingelsheim, but I have isolated from a case of phlegmonous cellulitis, and from one of septicæmia, a streptococcus presenting a distinct grayish-white growth upon potato. Von Lingelsheim made no use of one of our most valuable differentiating media, viz., sterilized milk colored with litmus. In this medium the common streptococcus pyogenes produces a very firm coagulum with separation of

nearly colorless serum, as has been pointed out by E. Fränkel. I have from different sources isolated pathogenic streptococci which do not coagulate milk, although they change the color of the litmus to a lilac pink, indicating the production of a certain amount of acid.

While we must admit that all inflammatory affections caused by the pyogenic staphylococci may be produced also by streptococci, and, with the probable exception of erysipelas, the reverse also holds true, nevertheless we are not prepared to accept the statements of Levy and some other recent writers that the character of the microörganisms, whether staphylococci or streptococci, has no influence upon the symptomatology of the disease. In conformity with most investigators, we have found the staphylococci prone to form circumscribed areas of suppuration, whereas the pyogenic streptococci have a tendency to produce spreading phlegmons with lymphangitis and a wide zone of surrounding redness and inflammatory œdema. It is the custom in our gynecological wards to isolate the operative cases in which streptococci are found at the time of the operation in the seat of the disease, or subsequently in the wound.

Of other pyogenic cocci we have found the staphylococcus pyogenes citreus twice in abscesses, the staphylococcus cereus albus three times in combination with other bacteria in suppurating wounds, the diplococcus pneumoniæ once in a fibrinous peritonitis, and the micrococcus tetragenus once, together with the staphylococcus aureus in an abscess of the lung.

The list of bacilli which may be concerned in suppurative and other inflammatory affections is much longer than was formerly supposed, and is likely to be still further extended. Those which we have chanced to encounter are: the bacillus pyogenes fœtidus, twice in abscesses containing bad-smelling pus; the proteus Zenkeri, once in pure culture in an ovarian abscess with purulent salpingitis; a bacillus apparently identical with the bacillus emphysematis maligni of Wicklein, once in an emphysematous cellulitis of the arm; a bacillus apparently identical with the bacillus enteritidis of Gärtner, in the brain and other organs of an infant three months old with cerebral abscess and meningitis following operation for imperforate anus; the typhoid bacillus, once in pure culture in an osteomyelitis of the ribs following typhoid fever; a hitherto undescribed bacillus, rapidly liquefying gelatin and characterized by rapid solution or peptonization of milk, without coagulation, once in peritonitis; bacilli which could not be cultivated in our ordinary culture media, in three cases of suppurative inflammation; and the bacillus coli communis, fifteen times.

As these bacillary infections are far less common than those caused by micrococci, I shall take some other occasion to describe them, and here shall ask your attention only to one group, viz., those associated with the bacillus coli communis, as they have been relatively common in our experience and present some points of especial interest.

The first observation of the bacillus coli communis in connection with wound infection was made by Tavel, in 1889. This has been followed by a few isolated observations of this organism either in the unchanged organs of the body or in suppurations, until recently A. Fränkel reports its presence in nine out of thirty-one cases of peritonitis. I first came across this bacillus in the organs of the body in 1890, in a case of multiple fat-necrosis with pancreatitis, which I reported to the Association of American Physicians. As in this case diphtheritic colitis existed, it seemed probable that the lesion of the intestine opened the way for the entrance into the circulation of this inhabitant of the healthy intestinal canal. This view subsequent experience has confirmed, for I have already isolated in pure culture from the internal organs the bacillus coli communis in twenty-five autopsies where some distinct lesion of the intestinal mucous membrane existed, such as ulceration, diphtheritis, hemorrhage, traumatic injury, and I have almost uniformly failed to find it outside of the intestine when no demonstrable lesion of the mucous membrane existed. I am therefore prepared to say that this bacillus is an extremely frequent invader in intestinal disease, although I have no evidence to offer that it does any harm except under certain especial conditions. The autopsies were in nearly every case made within a few hours after death, once in less than one hour. Moreover, the colon bacillus does not invade the blood and organs in the process of post-mortem decomposition.

The cases in which we have found the colon bacillus under circumstances pointing to its pathogenic action have been as follows: perforative peritonitis, four cases; peritonitis secondary to intestinal disease without perforation, two cases; circumscribed abscess, three cases; and laparotomy wounds, six cases.

Its presence, several times in pure culture, in laparotomy wounds treated aseptically, although apparently not a source of serious trouble, was not a matter of indifference. It was generally accompanied with moderate fever and a thin, brownish, slightly purulent discharge, of somewhat offensive, but not putrefactive odor. The smooth and rapid healing of the wound was interfered with. In some of the cases there was evidence of intestinal disorder; in others this was not apparent, and infection from without could not be excluded.

For the purposes of the present discussion, perhaps the chief interest of our observations concerning the colon bacillus is that they furnish an illustration of the possible predisposition to infection afforded by intestinal lesions, and also give an example of the much-disputed auto-infection.

Of suppurative inflammations which we have examined bacteriologically with negative result, may be mentioned abscesses in which the bacteria were presumably dead, several hepatic abscesses caused by the amœba dysenteriæ, and many cases of suppurating buboes and of pyosalpinx, doubtless caused by the gonococcus.

From the foregoing brief summary, mainly of our own limited experience, it is clear that the bacteria which may be concerned in surgical infections are many, but the pyogenic cocci of Ogston, Rosenbach, and Passet far outrank in frequency, and therefore in importance, all other bacteria combined.

In view of the more practical matters to be considered, we cannot tarry long over the theories of suppuration, interesting as just this part of the subject is at the present time.

There are very good reasons to believe that the process of suppuration serves a useful purpose, and is one of the most important and efficient weapons employed by Nature in combating invading micro-organisms. Man is not subject to those forms of septicæmia, common in many lower animals, in which enormous numbers of bacteria are present in the blood ; but, on the other hand, he is particularly subject to suppurations and other localized inflammations. The same microörganisms, for instance the diplococcus pneumoniæ and the bacillus anthracis, which in many of the lower animals invade the blood in large number, cause in man localized inflammations. In the experimental septicæmias of lower animals there is an unmistakable relation between the extent of the local reaction at the point of inoculation on the one hand, and the duration of life and number of organisms present in the blood on the other. The more extensive and intense the local reaction, the fewer, as a rule, are the bacteria found in the blood and the longer the duration of life. There are two varieties of the swine-plague bacillus, the one kills rabbits in twelve to eighteen hours with trifling local reaction and a large number of bacilli in the blood, the other produces extensive purulent infiltration around the site of subcutaneous inoculation and permits the animals to live for several days, and at the autopsy very few bacteria are found in the blood. In a susceptible animal the virulent anthrax bacillus produces an acute septicæmia, the attenuated bacillus a local abscess. There is even experimental evidence that if inoculation of a suscepti-

ble animal with the virulent anthrax bacillus be speedily followed by inoculation at the same point with a pyogenic organism so that suppuration soon ensues, the development of anthrax septicæmia may be warded off and the animal recover. It seems reasonable to infer, when the same organism produces in one animal a rapidly fatal septicæmia without local reaction and in another species only a local abscess, that the latter animal is protected by the barrier of suppuration. As is well known, the fatal infections from wounds received at post-mortem examinations are not generally those where marked local reaction with suppuration appears at the seat of the often trifling injury.

Exactly how abscess formation checks the invasion of bacteria we do not know. That bacteria may die, often in a short time, in pus both within and outside of the body, has been demonstrated. The leading theories are these : leucocytes and other cells act as phagocytes, taking into their bodies the bacteria and killing them ;—the wall of leucocytes and other cells at the margin of an abscess acts as an obstacle to the passage of the bacteria into the surrounding tissues ;—pus contains chemical substances injurious to bacteria or antidotal to their toxic products ;—the bacteria starve in pus, not being able to assimilate such concentrated food. Something can be said in favor of each of these theories, more in favor of some than of others, but none is proven and we cannot stop to discuss them here.

That pyogenic bacteria set up suppuration by chemical substances produced by them, seems to be proven. The zone of necrosis around these bacteria which can be demonstrated as the first effect of their lodgment in the tissues points to such chemical action. Moreover, from cultures of pyogenic cocci several chemical products have been obtained capable of causing suppuration. The most interesting observations here are the recent ones of Buchner and his pupils, who have found the proteid constituents of many bacteria capable of producing suppuration. These bacterio-proteins of Buchner possess in a remarkable degree the property of positive chemotaxis, that wonderful quality by which certain chemical substances influence the leucocytes to migrate from the vessels and move actively toward them. A flood of unexpected light seems destined to come from the studies of chemotaxis to illumine many dark problems in pathology.

Since we know that the chemical products and constituents of certain bacteria are the direct agencies in the production of suppuration, it is less surprising to find that various other chemical substances are likewise able to cause suppuration. But important as this fact is for the theory of suppuration, the demonstration that these other chemical

irritants, such as turpentine, nitrate of silver, etc., can cause suppuration has no especial bearing upon the ordinary suppurations in human beings.

We come now to the consideration of a division of our subject beset with difficulties at every turn, but one no less interesting to the surgeon than to the bacteriologist.

How are we to explain the extraordinary variability in the effects produced by the pyogenic cocci? The specific infectious agents with which we first became familiar, the bacteria of the natural and of the experimental septicæmias of lower animals, are nearly constant in the effects which they produce when inoculated in small quantity into susceptible animals. Not so with the pyogenic cocci. Here we meet the most puzzling differences. We find the same coccus in the most insignificant epidermal pustule which we find in a dangerous phlegmon, in osteomyelitis, in pyæmia, in septicæmia, in acute ulcerative endocarditis. The manifold varieties of puerperal fever, which we now know to be a typical wound infection, may be caused by apparently the same streptococcus, producing a mild endometritis, a pelvic abscess, localized or general peritonitis, pyæmia or the most virulent and rapidly fatal septicæmia.

If we seek an explanation of these things by experimentation upon animals, we find that in order to get any positive effects at all it is often necessary to introduce enormous quantities of our cultures, containing vastly more bacteria than we can suppose to be concerned in the primary infection in human beings. If we inoculate smaller quantities, these can often be disposed of by the animal without any manifest symptoms.

It must be confessed that we stand here before problems many of which still await solution, but it will not do to pass them by on this occasion without some discussion, although time will permit me to touch upon only some of the salient points.

It is well to bear in mind that the inflammatory infections of wounds do not represent specific morbid entities in the same sense as do anthrax and typhoid fever, for example. The latter diseases are caused by a single specific germ and no other, and present a definite and characteristic clinical and anatomical picture, whereas the former correspond to the reaction of the body toward a great variety of noxæ and offer manifold variations in symptoms and lesions.

The quantity of a culture of the staphylococcus aureus required to produce suppuration is not the same for all tissues and all parts of the body. A mere trace, a fraction of a drop, of a dilute suspension of the yellow staphylococcus in salt solution when injected into the rab-

bit's eye will set up a suppurative inflammation. It takes a larger amount of such a suspension to produce an abscess in the loose subcutaneous tissue of the back than in the dense tissue of the ear of a rabbit or in muscular tissue. Enormous quantities, five to ten cubic centimeters and more, of the suspension can be injected often without effect into the normal peritoneal cavity of rabbits and dogs, as has been shown by the well-known experiments of Grawitz and his pupils, confirmed by several other investigators.

It is probable, as claimed by Grawitz, that this difference in the behavior of different tissues depends in large part upon the rapidity with which the injected material, more particularly the toxic substances, are absorbed. But we must also reckon with a predisposition apart from this in the normal tissues, for the introduction even of very large numbers of staphylococci into the circulation of rabbits is followed by the formation of abscesses only in certain situations, mainly the kidneys, heart and certain muscles, although we must suppose that the cocci have been carried to all parts of the body.

That there are variations in the virulence of different cultures of the pyogenic cocci is admitted by most writers and may be inferred from the discrepant results of various experimenters as regards the amount of the culture required to produce suppuration. These discrepancies cannot be explained wholly by different conditions of the experiments. We have found no especial difference in the result, for example, whether we introduced into the peritoneal cavity of dogs cultures of the staphylococcus aureus according to Grawitz's method, or according to Pawlowsky's method, or by a small laparotomy wound. By one as well as by another method we were able to inject 5 c.c. and often more of a suspension in salt solution of the yellow staphylococcus without any appreciable effect.

In order to test this matter of varying virulence, I have injected into the ear veins of rabbits bouillon cultures, forty-eight hours old, of the staphylococcus aureus obtained from many different sources. Considerable variations in virulence were found to exist both in the original cultures and in the successive generations of the same culture. The most virulent cultures were one from a beginning furuncle and one from a fresh peritonitis. The injection of 0.1 c.c. of these cultures caused the death of the rabbit in twenty-four hours with a large number of staphylococci in the blood and many necrotic foci in the kidneys. After the second generation the virulence was lessened. From a case of hypertrophic cirrhosis of the liver without suppurative complications a moderate number of colonies of the staphylococcus pyogenes aureus were found in cultures made from

the liver. 1.5 c.c. of bouillon cultures, forty-eight hours old, of this staphylococcus were injected without any effect into the ear-veins of two rabbits, the animals being still alive eight months after the injection. These extremes are met only exceptionally. In the great majority of cases we have found the injection of 0.2 to 0.3 c.c. of bouillon cultures sufficient to kill the animal in four to seven days with the usual abscesses in the kidneys and heart and occasionally elsewhere. As a rule there was no material change in the degree of virulence for many successive generations, but sometimes without any apparent cause there would occur a marked weakening of the virulence either after a few generations or after many.

Our conclusions from these experiments are that while variations in virulence occur and may explain in large part the varying results of different experimenters operating upon animals under similar conditions, they are not sufficient in degree or in frequency to afford adequate explanation of the great differences in the effects of the pyogenic cocci upon human beings, or at least can do so only in part.

How far can we apply to human beings the experiments showing the great tolerance of animals toward the pyogenic cocci? The experimental evidence upon this point is naturally scanty, but such as we possess indicates that man is not equally tolerant, that his tissues respond more readily by suppuration to inoculation of pyogenic cocci. The experiments upon this point of Garré, Bumm, Bockhart, Fehleisen, Waterhouse—and these names should not be mentioned without expressing the debt of gratitude which science owes to them—are too well known to necessitate here any statement of their results. But while these experiments appear to indicate less immunity on the part of human beings toward the ordinary staphylococci of suppuration—a matter, however, which cannot be considered absolutely certain—they have also demonstrated that the difference, if it exists, is only one of degree, and that large numbers of the pyogenic cocci may be inoculated into human tissues without effect. Waterhouse, for example, injected under the skin of the abdomen and of the scrotum 0.25 c.c. of a suspension of the staphylococcus aureus, made by mixing one loopful from an agar culture with 5 c.c. of water, and the result was completely negative.

It is true that undue emphasis should not be laid upon the negative results, for there are equally trustworthy experiments with positive result, showing that even small quantities of suspensions of the pus organisms may cause suppuration, both in animals and in human beings.

That there exist bacteria capable of producing abscesses regularly, even when inoculated in very small quantity into animals, is proven by the discovery by Dr. Bolton of a hitherto undescribed bacillus in garden earth. This bacillus, for cultures of which I am indebted to Dr. Bolton, who will hereafter publish its description, produces with certainty localized abscesses when inoculated in small amount into the subcutaneous tissues of rats, mice, and rabbits. When injected into the circulation it causes multiple abscesses in the kidneys, joints, bones, and other situations.

Inasmuch as it is by their toxic products that the pyogenic bacteria do injury, it is not surprising to find that it makes a great difference in the result whether these bacteria enter the tissues already equipped with a reserve force of this poisonous material, or must begin the fight unarmed. There is abundant experimental evidence to show that even in very small number the pus-producing micrococci will cause suppuration if they are accompanied, or soon preceded or followed, in sufficient amount and concentration by various toxic substances which are present in pure cultures of the cocci, and the extent of the inflammation bears a relation to the quality and quantity of these substances. The experiments and researches of many investigators, such as Hankin, Brieger and Fränkel, Buchner, Dirckinck-Holmfeld, Grawitz, Leber, Dubler, Kronacher, Ribbert, have shed light upon this subject. It would seem as if the issues of the battle between the invading micrococci and the tissues depend often upon the first blow ; and if the invader can strike this with the aid of powerful weapons which he has forged before he enters, the victory, for the time at least, is with him.

This matter of accompanying toxic substances is probably of great importance in our understanding of the potentialities of the living agents of wound infection as they occur under natural conditions. Here we have to do, not with pure cultures of the pyogenic cocci, still less with those that have been washed in sterilized salt solution or water, but with pus-producing organisms which have come from all sorts of sources, which have been engaged in very different activities, which have been growing under various conditions or have been long dormant, and which are mixed with many kinds of bacteria. There is proof that under some of these conditions the infectious material may possess a degree of virulence with which we are not familiar in our artificial cultures. When a strong, healthy man (I have now in mind such a case in a medical student) dies in a few days from septicæmia caused by the inoculation of a mere scratch on the finger with fluid from a puerperal peritonitis, it is the quality of the infectious material which brought about the fatal result, and not any especial

predisposition of the individual. When we find, as has been done, that the peritoneal fluid contains in pure culture the streptococcus pyogenes, and that the same organism is present in pure culture in the patient accidentally infected with this fluid, the observation is just as convincing and clear in its interpretation as if the experiment had been made intentionally upon an animal. No number of experiments showing that millions of apparently the same species of micrococcus can be injected in artificial cultures into the peritoneal cavity of dogs and rabbits can do away with the force of such an observation. No surgeon, no obstetrician, however strong may be his trust in the defensive powers of the animal tissues and fluid, would willingly permit the smallest particle of that peritoneal fluid to come into contact with a fresh wound or the uterus after childbirth.

The differences in virulence which have been found to exist between inflammatory exudates from various sources containing pyogenic bacteria are much greater than those observed in the cultures of the same bacteria on artificial media. To explain this, some assume that the differences in virulence pertain to the pyogenic cocci as such, that they are specifically endowed with different biological attributes; while others think that the varying virulence relates not so much to the bacteria as to the character of the toxic substances with which they are associated. In favor of the latter view, which is the one advocated by Bumm, Fehleisen, Chantemesse, and others, may be cited such observations as that of Bumm, who found that the injection into the peritoneal cavity of a rabbit of a quarter of a drop of fluid from a case of acute septic puerperal peritonitis quickly killed the animal with peritonitis, whereas the streptococci artificially cultivated from the same fluid were much less virulent; or the experiment of Fehleisen, showing that a minimal quantity of an artificial culture of the staphylococcus aureus added to a little of the clear serum obtained from the germ-free zone of inflammatory œdema around a spreading cellulitis was capable of producing extensive abscesses, whereas the mixture of the same organism with water had no such effect. The question is still an open one, and very likely both factors are concerned.

We have thus far confined our attention to the microörganisms of infection, and have said nothing concerning the conditions predisposing to infection in the exposed individual. Everybody believes in the doctrine of predisposition, some more than others. The tendency at the present time is certainly not to minimize its importance. Predisposition is a term to conjure with. It is often made to explain in a vague sort of way things which we do not understand. Nevertheless it is a very real thing, and we cannot pass it by here without notice,

even if this must necessarily be very brief. Every surgeon knows that wounds in some persons do much better than in others, and that some kinds of wounds are much more prone to suppurate than others.

The interesting studies upon immunity which have shed so much light upon the nature of predisposition toward some infectious diseases have not as yet cleared up the question of immunity against the pyogenic cocci. We know that the healthy tissues can dispose of a certain number of these cocci under ordinary circumstances, but how they do it we do not know.

An experiment of Roger is suggestive. He found that the streptococci of erysipelas grew as well in the blood-serum of rabbits rendered immune as in the blood-serum of other animals, but that in the former they lost their virulence. As we now know that the protective influence of the blood-serum of immune animals consists quite as much in the power to destroy the poisons produced by bacteria as in the power to kill the bacteria directly—already demonstrated examples of this are diphtheria, tetanus, and septicæmia produced by the diplococcus pneumoniæ—it is not unreasonable to suppose, in the light of Roger's experiments, that this antidotal capacity of the blood and animal fluids may be one of the means employed by Nature in disposing of the pyogenic cocci. That these cocci are not directly killed by the extravascular blood-serum of rabbits, dogs, swine, and human beings, or if at all in very small number, we know. On the other hand, this serum is an excellent medium for their growth. But if the toxic products of the bacteria are destroyed by the fluids of the body, the bacteria can do no harm, and are at the mercy of the tissues, as has been shown by the recent brilliant researches of G. and F. Klemperer on the diplococcus of pneumonia. When we have a clearer insight into the nature of immunity against the pyogenic bacteria, our understanding of the conditions underlying the infection of wounds will be greatly advanced.

I cannot undertake to discuss all the general conditions of the body, such as diabetes, syphilis, alcoholism, anæmia, obesity, typhoid and other fevers, Bright's disease, etc., which have been regarded as predisposing causes of infection with the pyogenic cocci, some of these diseases upon most conclusive clinical evidence. Gärtner has recently brought forward evidence derived from experiments on animals showing that general anæmia and hydræmia render easier the infection with small quantities of the staphylococcus aureus, and Ribbert has demonstrated that the presence of toxic products of the same microörganism in the circulating blood favors the development of foci of suppuration, a fact which evidently bears upon the pathology of pyæmia and of some cases of furunculosis, as well as upon the importance of evacuat-

ing pus. An instance has already been given of the predisposition to infection afforded by intestinal lesions. In dismissing thus hastily the matter of general predisposition to suppuration, it will not be understood that these few words are a measure of the importance of the subject. I believe that the surgeon cannot be too thorough in the examination, before contemplated operations, of all the important organs and functions of the body, and that, wherever possible, he should endeavor to put the patient into the best possible condition of health before undertaking a severe operation.

Of very immediate practical interest to the surgeon is a knowledge of the various conditions in and about a wound which favor the lodgment and development of pyogenic bacteria. In a general way it may be said that anything which interferes with the integrity of the living tissues in a wound is a predisposing cause of suppuration, in case suitable microörganisms gain entrance. Experiments have shown that the necroses produced by chemical irritants, such as carbolic acid and corrosive sublimate, favor the multiplication of the microörganisms of suppuration. Dr. Halsted has shown that the irrigation of fresh wounds by a solution of corrosive sublimate as weak as 1 to 10,000 is followed by a distinct line of superficial necrosis demonstrable under the microscope.

We are not so well informed as to the influence exerted by blood in a wound. On the one hand, Von Bergmann and most modern surgeons lay the greatest stress upon prompt and careful hæmostasis in surgical operations; on the other hand, Schede has revived and more fully developed an old method of treatment, by which a certain class of wounds are permitted to fill with a blood-blot, and he and other surgeons have obtained rapid and aseptic healing by this method. Is this blood-clot, as such, a source of danger in the same sense as dead tissue is? As has already been mentioned, fresh blood-serum does not possess any such germicidal power over the pyogenic cocci as it does over the typhoid bacillus and many other bacteria. Not being able to find any direct experimental evidence upon the point, I have, with the assistance of Dr. Howard, made a large number of experiments upon dogs. The operations were done with strict antiseptic or aseptic precautions. In most of the experiments a cavity was chiselled out of bone, and this and the rest of the wound were allowed to fill with a coagulum of blood, the conditions pertaining to similar operations in human beings being observed. The blood-clot, after its formation, was inoculated with a culture of the staphylococcus aureus, either by injecting into it a few drops of a fresh bouillon culture or by inserting a platinum loop carrying a bit of the growth on agar. The outcome

of the experiments was that the so-called organization of the blood-clot went on as it does in human beings, and the wounds did not suppurate. The staphylococci survived, at least for many days, in the clot, but they did not appear to multiply. This result is in conformity with the experience of Grawitz, who found that the aureus lives for a long time, although it does not multiply, in blood-coagula outside of the body, and that no development of this organism takes place in a solidified mixture of equal parts of nutrient gelatin and blood.

It is not my province to consider the extent of application of the method advocated by Schede to human surgery, nor the advantages of retaining the material employed by Nature in filling up cavities and pockets in fresh wounds as against the insertion of sterilized extraneous material and the obliteration of the dead spaces by deep stitches, which, without great care, are liable to strangulate tissue, produce undue tension, and interfere with the circulation.

Where the healing of the wound by the blood-clot method is not directly purposed, undoubtedly it is important for its aseptic course to check the oozing of blood and to prevent the unintended formation and retention of blood-coagula whose presence is not arranged for by the surgeon in the management of the wound. That loss of blood, as such, predisposes to suppuration has already been mentioned.

In contrast with the negative results of the experiments just mentioned stands a series of positive ones which illustrate the readiness and uniformity with which suppuration of an infected wound ensues which contains masses of tissue strangulated by ligature. These wounds were inoculated with the same cultures which yielded negative results as regards the infection of the blood-clot.

We have made also a large number of experiments upon dogs by ligating portions of the omentum and then injecting cultures of the staphylococcus aureus, into the peritoneum. In most of these cases general peritonitis developed, in some localized peritonitis, and in some no peritonitis followed the inoculation.

In order to demonstrate the influence of foreign bodies in favoring suppuration, we inserted into the peritoneal cavity of nine dogs pieces of potato presenting a growth of the staphylococcus aureus, and in every instance general peritonitis developed, although in no case was the insertion of similar pieces of sterilized potato followed by peritonitis; and the injection of 1 c.c. bouillon culture of the staphylococcus aureus into the peritoneal cavity of twenty-three dogs was not followed in a single instance by peritonitis.

There is a gratifying harmony between the views entertained by bacteriologists concerning the power of the living tissues to overcome

a certain number of pyogenic bacteria, and the tendency of the modern surgeon to respect these tissues more and more, not to destroy their vital capacities by the unnecessary application of strong chemical disinfectants, not to bruise them, not to make them too tense, not to strangle them, not to suffer the presence in wounds of spaces and foreign bodies, which remove bacteria from the influence of the living tissues and fluids.

From this necessarily hasty and imperfect survey of this division of our subject, it is apparent that, while there is no reason to doubt that the pyogenic cocci are specific agents of infection, the effects which they produce depend upon a variety of conditions, such as the source, the number, and the virulence of the micrococci, the accompanying toxic substances, the part of the body invaded, the readiness of absorption, the presence of foreign bodies and of pathological products, the general state of the patient, and the condition and handling of the wounded tissues.

In giving due weight to each of these factors one should not forget that the infectious material may exist under natural conditions, in a state capable of causing traumatic infections just as directly, just as certainly, just as independently of predisposition, as infection of a susceptible animal takes place with the anthrax bacillus.

As to the various ways by which pathogenic bacteria may gain access to wounds, there is at the present time general agreement of opinion that the greatest danger is from contact with infected hands, instruments, and other objects. The danger of infection by contact is a lesson which has been learned no less by bacteriological workers in the laboratory than by practical surgeons and obstetricians.

The possibility of infection from the air, insignificant as it may be in comparison with contact infection, cannot be ignored quite as much as some seem inclined to do. The staphylococcus pyogenes aureus has been repeatedly found in the dust floating in the air, particularly of surgical wards where there are suppurating cases. The streptococcus erysipelatos was found by Von Eiselsberg in the air of a ward containing cases of erysipelas and the streptococci found by Prudden in the air of hospital wards were probably identical with this. When we had more confidence than we now have in the power of chemical disinfectants to destroy all bacteria which might accidentally get into a wound during a surgical operation, it seemed proper to disregard the air as a source of infection, and no less a surgeon than von Volkmann could say, "Auch auf einem Abtritte würde ich dreist operiren wenn die Hände rein wären." A privy, by the way, is not the most dangerous place which he could have selected.

Now that our trust in chemical disinfectants for the purpose named is shaken, and that what is called aseptic surgery is the watchword of the day, I believe that a surgeon who aims at the best will try to have the air of his operating-room as free from germs as possible, and will have it so constructed that the floor and walls and all that is in it can be readily cleaned and disinfected. He will regard the influence of currents of air and of commotion in the room in stirring up dust, and will not ignore the value of moisture in laying dust and in keeping it in its place. These suggestions may seem pedantic when the whole tendency of surgery now is to simplify technique and to throw overboard unnecessary ballast, but they appear to me to rest upon bacteriological facts which should not be ignored.

An example has already been given in this paper of auto-infection from the intestinal canal by the bacillus coli communis. The not infrequent invasion of the pyogenic cocci in typhoid fever, diphtheria, scarlet fever, and other diseases with lesions of the alimentary tract, are probably explicable partly by these lesions opening a passage for the bacteria into the circulation, and partly by the predisposition afforded by the presence in the body of toxic substances belonging to the primary disease. It is known that the pyogenic cocci are often present in the alimentary canal. For instance, in a case of perforative peritonitis from typhoid fever, recently examined in my laboratory, there were isolated from the peritoneal exudate, not in single but in many colonies on the roll cultures, the staphylococcus aureus and the streptococcus pyogenes, in addition to the typhoid bacillus, the colon bacillus, and an unidentified bacillus liquefying the gelatin.

Rinne observed in his experiments on dogs that the injection of sterilized putrid fluids together with staphylococci into the peritoneal cavity was followed by suppuration of all open wounds, which otherwise healed kindly, but that subcutaneous wounds were unaffected. The bacteria found in the suppurating open wounds, however, were not those injected, but were derived from the air. This is unquestionably an interesting and important observation, but he goes too far in supposing that such wounds, as well as other loci minoris resistentiæ, may not become infected from pyogenic cocci in the circulation, as has been demonstrated by the experiments of De Wildt, Waterhouse, and others.

That even under the most unfavorable conditions of general infection a wound may heal by first intention is known to surgeons. In one of our cases, for example, the patient soon after an extensive operation for removal of a cancer of the breast, developed diphtheritic ulcerative dysentery ; and at the post-mortem examination were found,

in addition to the dysentery, pneumonia, abscess of the lung, and fresh pleurisy, with wide distribution of the staphylococcus aureus; nevertheless, the operation wound had remained perfectly healthy without a trace of suppuration.

Into the burning question of auto-infection from the genital tract in puerperal women I cannot enter, save to say that the pyogenic cocci seem to be present only exceptionally in the normal tract and do not thrive there if intentionally put in, but that they are found in pathological utero-vaginal secretions, when, of course, they may become a source of puerperal infection. The question is a difficult one and requires further investigation. This passing mention is only intended to indicate that the subject belongs to our theme and may appropriately enter into the discussion.

I must beg permission to defer for a few moments the question of infection from the skin of the operator and of the patient.

That an aseptic wound is not necessarily one free from bacteria has been known since the early days of antiseptic surgery, the subject having been investigated by Ranke, Demarquay, Fischer, Schüller, Watson Cheyne, and others. Kümmell found that pieces of muscle, adipose tissue, or connective tissue taken from fresh wounds immediately after irrigation during the entire operation with corrosive sublimate solution 1 : 10,000, contained bacteria, and the same result was obtained after frequent washing with sublimate solution 1 : 1000.

The most recent investigation of the bacteria in fresh wounds treated antiseptically is by Bossowski, who found, of 50 cases, 10 with negative and 40 with positive result from the bacteriological examination. He found the staphylococcus albus 26 times, the staphylococcus aureus 9 times, the streptococcus pyogenes 2 times, and other organisms, non-pathogenic, 8 times. He several times found a coccus, liquefying gelatin after several days, growing at first white and then slowly turning yellow, and incapable of producing suppuration in rabbits or in wounds. This he proposes to call staphylococcus gilvus. In every case in which the staphylococcus aureus or the streptococcus pyogenes, with or without other organisms, was present, suppuration occurred. On the other hand the staphylococcus albus produced generally no interference with the healing of the wound, but sometimes it caused a little suppuration of the drain canal or a stitch abscess. In the majority of cases there was absolute *prima intentio*. The small number of the colonies indicated meagre development in the wound.

Drs. Ghriskey and Robb have made under my observation the bacteriological examination of 45 laparotomy wounds treated with strict antiseptic precautions in the gynecological wards of the Johns Hop-

kins Hospital. The method of treatment and the technique adopted for obtaining the cultures have already been published by Dr. Robb, in the *Bulletin of the Johns Hopkins Hospital*, July, 1891.

Of these 45 cases the result was negative in 14, positive in 31, or nearly 69 per cent. of the cases. The organisms found were the staphylococcus albus 19 times, the staphylococcus aureus 5 times, the bacillus coli communis 6 times, the streptococcus pyogenes 3 times, once alone and twice in combination with the albus. Of the cases with the aureus in only two was there reason to suspect infection from without; in the others this organism was present in the seat of disease for which the operation was performed. In the first case with streptococcus pyogenes the operation was performed for an ovarian abscess which contained streptococci in large numbers; the other two cases probably became infected in some way from the first patient.

In all of the cases presenting the staphylococcus aureus or the streptococcus pyogenes the wound suppurated, and, as a rule, the general condition of the patient was bad.

In many of the cases where the white staphylococcus was found there was no disturbance in the healing of the wound. This was true especially when the organism was found in small number, and when it made its first appearance subsequent to the first dressing, which took place usually twenty-four to forty-eight hours after the operation. In many cases, however, the white coccus was the cause of more or less trouble, although rarely of a serious nature. It was found to travel down to the bottom of the wound along the side of the drainage-tube, and any purulent discharge attributable to its presence was usually confined to the tract occupied by the drainage-tube, so that the drainage-tube distinctly favored the invasion and growth of the coccus. Sometimes fever without suppuration seemed attributable to the presence of this coccus. That this organism is the most frequent cause of the ordinary stitch abscesses has already been mentioned.

Under especially favorable circumstances this white staphylococcus may cause peritonitis, as is shown by a fatal case of hystero-myomectomy where at the autopsy a volvulus of the ileum was found. The stump and the laparotomy wound both looked healthy, but there was a fresh fibrino-purulent peritonitis clearly starting from that part of the peritoneum agglutinated to the inner edge of the laparotomy wound. This part corresponded to the peritoneum covering the twisted ileum. The twist was not so tight as to have produced gangrene or even a marked hemorrhagic condition; but it had interfered sufficiently with the circulation and the nutrition of the peritoneum

to have rendered this a favorable soil for the growth of an otherwise comparatively innocent bacterium, our white staphylococcus having been found in pure culture in the inflamed peritoneum.

The efforts to find out the origin of this very common inhabitant of wounds, treated aseptically or antiseptically, have led us to some interesting and new observations concerning the bacteria of the skin.

The skin may have all sorts of bacteria upon its surface, but, like the mouth and the intestine, in addition to these it has its own distinctive bacterial flora.

If the hands be thoroughly scrubbed with soap and hot water with a sterilized brush, or if this be followed by washing the hands in sublimate solution and the mercury be precipitated by sulphide of ammonium, the cultures obtained from scrapings of the skin so treated will generally be found to contain, as the prevailing organism, the white staphylococcus, and often this will appear in nearly or quite pure culture.

But the most important point is that this coccus is very often present in parts of the skin deeper than can be reached by any known means of cutaneous disinfection save the application of heat. We were directed to this conclusion first by experiments on animals. Then the observation of the same white coccus in pure culture time after time in wounds where every possible antiseptic precaution had been taken, pointed to the same deduction. More conclusive evidence was afforded by the examination of skin stitches in cases where at the time of the operation it was proven that the silk used for stitches was sterile and that the surface of the skin after thorough disinfection was sterile. The silk sutures when removed were proven both by microscopical examination and by roll or plate cultures to contain with great regularity the white staphylococcus, often in considerable number, often enclosed within leucocytes, and this not only where a stitch abscess had formed but also where there was not a trace of suppuration or visible reaction around the stitch.

A crucial experiment is the following : The skin is thoroughly disinfected, in the manner to be presently described, so that culture-tubes of nutrient agar or gelatin inoculated by scrapings from its surface remain sterile. A silk thread, sterilized by steam and proven by culture methods to be sterile, is passed one or more times by means of a sterilized instrument through the skin, is withdrawn, and at once a tube of melted nutrient agar is inoculated with the thread and rolled. This amounts to a ready means of making cultures directly from the deeper layers of the epidermis and the skin, and is a method applicable for many purposes to the bacteriological examination of the skin.

By this method the presence of the white staphylococcus, often in pure culture, has been repeatedly demonstrated in parts of the epidermis deeper than were acted upon by any methods of disinfection of the surface of the skin. So far as our observations extend, and already they amount to a large number, this coccus may be regarded as a nearly, if not quite, constant inhabitant of the epidermis. It is now clear why I have proposed to call it the staphylococcus epidermidis albus. It possesses such feeble pyogenic capacity, as is shown by its behavior in wounds as well as by experiments on rabbits, that the designation staphylococcus pyogenes albus does not seem appropriate. Still, I am not inclined to insist too much upon this point, as possibly this coccus, which has hitherto been unquestionably identified by Bossowski and others with the ordinary staphylococcus pyogenes albus of Rosenbach, is an attenuated or modified form of the latter organism, although, as already mentioned, it presents some points of difference from the classical description of the white pyogenic coccus.

We can now understand how, without any flaw in the antiseptic technique of the surgeon, this microörganism may be present in wounds, and we have a satisfactory explanation of the frequent occurrence of stitch abscesses, although, of course, the inference should not be drawn that the white staphylococcus is the only bacterium which may be concerned in the production of these annoying complications.

How much practical importance attaches to the demonstration of this coccus in the deeper layers of the epidermis or the glandular appendages of the skin I am not prepared to say. The surgeon with good technique who does not bother himself about it is not likely to be severely punished by the behavior of his wounds. Those who put drainage-tubes and other extraneous substances into their wounds I think will have to consider it. Dr. Halsted, on the basis of researches on the bacteria of the skin and the difficulties of complete disinfection of the skin of the patient, has abandoned for nearly all wounds the use of skin stitches, the edges of the wound being brought together with admirable coaptation by subcutaneous sutures. The results, both as regards the scar and the aseptic healing of the wound, have been most gratifying. Stitch abscesses are, of course, avoided by this procedure.

Another coccus which we have found, although less frequently than the white coccus, on the surface and in the deeper layers of the epidermis, is one already referred to which corresponds to that called by Bossowski staphylococcus gilvus. This organism seems to bear about the same relation to the pyogenic yellow staphylococcus which our

epidermal white coccus does to the typical pyogenic white staphylococcus.

The staphylococcus pyogenes aureus we have found very frequently on the hands of surgeons and their assistants who have to do with suppurating cases of any kind. It may be present in this situation at least for several days after contact with surgical cases. It was met only exceptionally upon the hands of other persons.

The demonstration of microörganisms in layers of the skin deeper than can be disinfected by present methods suggests that more attention than seems now to be customary should be paid to the skin of the patient as a source of traumatic infections. It also admonishes us to receive with caution the statements recently made concerning the elimination in suppurative diseases of staphylococci by the sweat.

A considerable part of our work has been devoted to the subject of surgical antisepsis, and particularly to the disinfection of the skin. Dr. Abbott has conducted in my laboratory careful experiments regarding corrosive sublimate as a disinfectant against the staphylococcus pyogenes aureus, in which many fallacies in previous work on the same subject have been pointed out. In view of the time already consumed, I must ask permission simply to refer to Dr. Abbott's paper on this subject, already published in the *Bulletin of the Johns Hopkins Hospital* for April, 1891.

The conditions for the efficient action of chemical disinfectants have been found to be far more complicated and less easily controlled than was formerly supposed, and the substitution, wherever applicable, of the simple and certain methods of disinfection by heat, such as have been long employed in bacteriological laboratories, is to be commended. Chemical disinfectants still have their place for many purposes in the operating room, but their place is not in fresh, healthy wounds.

Thorough scrubbing of the skin with soap and warm water by a sterilized brush removes many bacteria, but not all, and it cannot be regarded as a satisfactory means of cutaneous disinfection.

The fallacy in previous work on disinfection of the skin with corrosive sublimate has been that in testing its efficiency the sublimate was not first precipitated by sulphide of ammonium or some other alkaline sulphide. If this precaution, to which attention was first directed by Geppert, be observed, it will be found that corrosive sublimate accomplishes much less than is generally supposed. Our revision of the work relating to cutaneous disinfection with sublimate has led to some curious and interesting observations, and to results which at first seemed paradoxical.

By examining the hands of surgeons who are in the habit of washing them daily in solutions of corrosive sublimate, it was found that the mercury becomes so intimately incorporated with the epidermis that its presence there can be demonstrated by means of sulphide of ammonium at least many days after any contact with mercurial solutions has taken place. Micrococci in the epidermis which have not been killed by washing in sublimate solutions, but which have been brought into such relation to the sublimate that even after prolonged washing of the skin with alcohol and water they will not grow on culture media until the skin is washed with sulphide of ammonium, may also remain a long time in the epidermis. Hence it may happen that prolonged scrubbing of the hands of such persons simply with soap and warm water may remove so many superficial bacteria that the cultures from the scrapings of the epidermis may show very few, sometimes even no, colonies; whereas, when this is followed by washing in sublimate and then in sulphide of ammonium, a much larger number of colonies appear in the cultures. This apparently paradoxical result, which is obtained only from the hands of those who have previously washed them in sublimate solution, has no reference to the application of the sublimate immediately after the soap and water, but is to be explained by the liberation, by means of sulphide of ammonium, of the bacteria held in check by the mercury used, it may be, several days before the experiment. The same result is, of course, obtained if the sulphide of ammonium be applied immediately after the scrubbing with soap and water. These observations upon the persistence of mercury in the epidermis and its long-continued inhibition of the growth of bacteria, make it necessary in all work upon disinfection of the hands to first precipitate the mercury with sulphide of ammonium whenever the experiments are to be made upon hands which have been washed in sublimate solutions, even if this has occurred a long time previously. Exactly what relation the mercury in the epidermis holds to the bacteria which it does not destroy, but whose growth in our nutrient media it prevents, we cannot say. We may, perhaps, think of these bacteria as enveloped in an albuminous combination of mercury. One thing is certain—that, when the sublimate has been as thoroughly washed off from the skin as possible with water, or has been applied days before, the nutrient gelatin or agar is not rendered unfit for the growth of bacteria by the mere presence of the small quantity of mercury carried into it with scrapings from the epidermis, for the bacteria which have reached the epidermis after the application of the sublimate—and these are often identical with those inhibited by the mercury—develop as usual. It is only those bacteria

which were originally brought into contact with the sublimate in some such manner as that suggested which will not grow until after the application of sulphide of ammonium, and it is not — as has been usually supposed in other observations of a similar kind in disinfectant experiments with sublimate—the alteration of the nutrient medium by the presence of a trace of sublimate which inhibits the growth of the colonies.

As to the practical efficiency of disinfection of the skin with solutions of corrosive sublimate, it is to be said that this agent, when properly applied, kills most of the bacteria upon the surface of the skin. The washing of the skin with alcohol immediately before the use of the sublimate increases its efficiency to a marked degree. If Fürbringer's method be carried out according to the strict letter of his directions it yields fair results, but it is not certain. If the mercury after employment of this method be precipitated by washing the hands in sulphide of ammonium, it will be found that the results are much less favorable than would appear by cultures made from the skin and under the nails, without the use of ammonium sulphide. It is especially the scrapings under the nails and around the matrix of the nails which yield positive results when ammonium sulphide is used, but often negative ones without this precaution. It need hardly be said that in our experiments all of the well-known, although often neglected, precautions to insure the full strength of the sublimate solutions were observed.

It may be urged that it is not necessary actually to kill the bacteria upon the skin ; it is sufficient if they are rendered incapable of growth, and as most of those which are not killed by the sublimate do not grow upon our ordinary nutrient media, it is reasonable to infer that they will not grow in wounds. This line of argument certainly deserves consideration ; nevertheless, there is no positive proof that these bacteria will not grow in wounds under some conditions, and surely one will feel safer with a method of disinfection which actually kills the bacteria.

I shall not detain you with the results of our experiments with other disinfectant agents. These will be published in a short time elsewhere. I shall simply state here that we have thus far obtained the best results in disinfection of the skin by the following method :

1. The nails are kept short and clean.

2. The hands are washed thoroughly for several minutes with soap and water, the water being as warm as can be comfortably borne, and being frequently changed. A brush, sterilized by steam, is used. The excess of soap is washed off with water.

3. The hands are immersed for one to two minutes in a warm saturated solution of permanganate of potash and are rubbed over thoroughly with a sterilized swab.

4. They are then placed in a warm saturated solution of oxalic acid, where they remain until complete decolorization of the permanganate occurs.

5. They are then washed off with sterilized salt solution or water.

6. They may then be immersed for two minutes in sublimate solution, 1:500.

The bacteriological examination of skin thus treated yields almost uniformly negative results, the material for the cultures being taken from underneath and around the nails. This is the procedure now employed in the gynecological and surgical wards of the hospital.

The principal conclusions of this paper may be summarized as follows :

The number of different species of bacteria, particularly of bacilli, revealed by the systematic study of traumatic infections is much greater than was formerly supposed. The pyogenic staphylococci and streptococci, however, are by far the most common causes of suppurative affections of wounds.

A coccus, which may appropriately be called the staphylococcus epidermidis albus, is a nearly, if not quite, constant inhabitant of the epidermis, lying both superficially and also deeper than can be reached by present methods of disinfection of the skin. This coccus is found frequently in aseptic wounds. It may be the cause of disturbances, usually of a relatively slight degree, in the healing of the wound, especially when drainage-tubes are inserted. It is the most common cause of stitch abscesses in wounds treated antiseptically or aseptically.

The bacillus coli communis is a frequent invader of various organs of the body in cases with ulcerative or other lesions of the intestinal mucous membrane. In such cases its presence is usually unattended by evidence of pathogenic action, but this bacillus may be associated with inflammatory affections of wounds, with peritonitis, and with abscesses.

There are many reasons for believing that the process of suppuration serves a useful purpose in combating bacteria and preventing their invasion of the circulating fluids and the tissues of the body.

The pyogenic bacteria set up suppuration by means of chemical substances produced by them and entering into their composition. The studies of chemotaxis have shed much light upon the mode of action of these substances.

The effects produced in the animal body by the pyogenic cocci are determined by many factors relating to the infectious agents and to the individual exposed to infection. There are differences in these effects depending upon the species of animal, upon the tissues and part of the body infected, upon the readiness of absorption from the infected part; upon the source, the number, and the virulence of the organisms; upon the nature and amount of the toxic substances accompaying and produced by the bacteria, upon general predisposing conditions of the body, and upon local conditions in a wound such as the presence of foreign bodies, of pathological products, of dead spaces, of bruised, necrotic, and strangulated tissues.

Infectious agents, as they occur under natural conditions, may posses greater virulence than the same bacteria in artificial cultures, and this probably depends upon accompanying toxic substances.

Results of experiments on animals explain clinical experience concerning the aseptic healing of wounds by the so-called organization of a blood-clot.

The tissues of a wound should be handled so as to interfere as little as possible with their vital capacity to overcome bacteria.

Although the greatest danger of infection of a wound from without is by direct contact, nevertheless the possibility of infection from the air should not be disregarded.

Auto-infection may take place by the entrance into the circulation and tissues of pyogenic bacteria from the alimentary and the genital canals, but there is no evidence that this can occur when these tracts are in a healthy condition. Moreover, with the requisite lesions of these tracts other general and local conditions of the body are important, if not essential, factors in bringing about pyogenic or septic infection.

The presence in the circulating blood and tissues of certain chemical products of pyogenic and of putrefactive bacteria, as well as that of various other injurious substances, favors the growth in wounds of septic and pyogenic bacteria, both of those which may be carried to the part by the circulating fluids and those which may enter from outside of the body.

Whenever we have been able to demonstrate the presence in wounds in human beings of the staphylococcus pyogenes aureus or of the streptococcus pyogenes the wound either was suppurating or subsequently it suppurated.

Only in the minority of cases were the aseptic wounds which we examined free from bacteria. By far the most common organism in these wounds pursuing an aseptic course is the staphylococcus epider-

midis albus, which without the presence of a drainage-tube or other foreign body rarely causes suppuration in the wound.

The presence of microörganisms in layers of the skin deeper than can be reached by existing methods of cutaneous disinfection points to the skin, especially to that of the patient, as a source of infection to be carefully guarded against.

The substitution so far as possible of subcutaneous for cutaneous sutures lessens the chances of infection from this source, and particularly those of stitch abscesses.

Wherever applicable in surgical antisepsis, disinfection by heat should be preferred to that by chemical agents.

Previous experiments to determine the efficacy of disinfection of the skin with corrosive sublimate are vitiated to a considerable extent by the failure to precipitate the mercury in the form of the sulphide before testing by culture methods its germicidal power on the skin.

The mercury may remain for days and weeks intimately incorporated with the epidermis.

Epidermal bacteria not killed by the sublimate may be brought into such relation with it that they will not grow in ordinary culture media until the mercury is precipitated as the sulphide, and such bacteria may remain for days and weeks in the epidermis.

The results of Fürbringer's method of disinfection of the skin are found to be less favorable when they are tested after precipitation of the mercury with ammonium sulphide than without this precaution.

The best results in cutaneous disinfection we obtained by a method in which permanganate of potash followed by oxalic acid plays the principal disinfectant rôle.*

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